



Metal Parts from Papercraft

Molds

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TOOLS:

- 11 hobby knife and spare blades (1)
- Computer with printer (1)
- Crucible (1)
- Crucible tongs (1)
- Gloves goggles long pants long sleeves (1)
- Hacksaw (1) with coarse blade
- Heat source (1)
- Scissors (1)
- Spray bottle (1) full of tap water
- Steel container (1) for molding sand

PARTS:

- Scrap metal (120 mL) to suit your heat source
- Sand (4 L) table salt or kitty litter can substitute
- Heavy paper card stock or scrap cardboard (1) as heavy as you can get through your printer
- Scotch tape (1)

SUMMARY

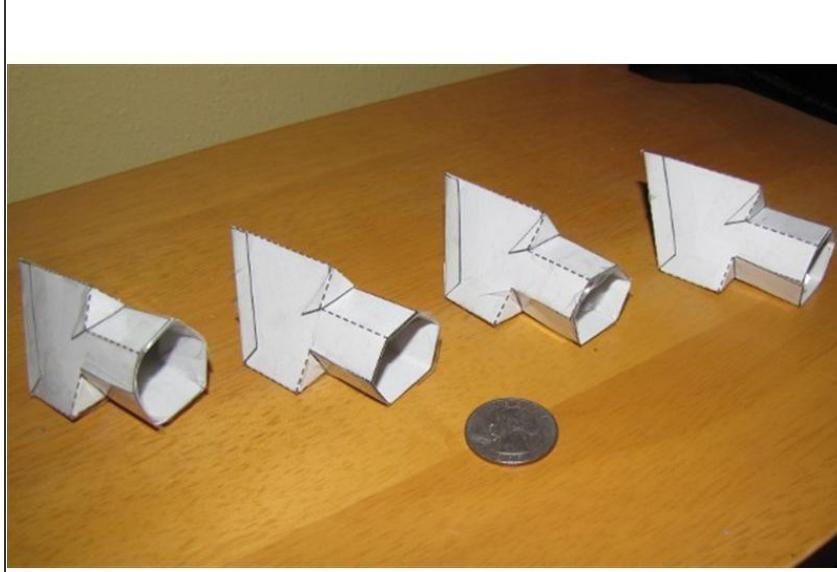
This project began when I read the following entry [#274] in Volume 1 of Popular Mechanics' 1913 *The Boy Mechanic*:

The round lead weight for shot-putting or hammer throwing can be cast in a hollow cardboard or pressed-paper ball, sold in department and toy stores for 10 cents. Cut a 1/2-in. hole in the ball as shown in Fig. 1 and place it with the hole up in damp sand and press or tamp the sand lightly around the ball as shown in the section, Fig. 2. Cover over about 1 in. deep. A wood plug inserted in the hole will prevent any sand falling inside. When the sand is tamped in and the plug removed, it leaves a gate for the metal. Pour melted lead into the gate until it is full, then, when cool, shake it out from the sand and remove the charred paper. A file can be used to remove any rough places. The dry paper ball prevents any sputtering of the hot lead.

This idea of a hollow card or paper form buried in plain sand as a sacrificial mold for poured metal parts interested me. As the internet papercraft explosion has taught us, paper is really not a bad medium for 3D design, especially for the cost. Software like [Pepakura Designer](#) will convert any 3D digital model into a papercraft one that can be printed out, cut out, folded up, and glued or taped together to make a reasonably accurate real-world replica of the original. What if, instead of using the paper as a positive representation, one were to use it simply as a negative space--a volume, supported by dry sand, that would survive just long enough to impart its form to molten metal poured inside?

As a first experiment, I designed a paper template for the pieces of a classic put-together puzzle often called "The Four Piece Pyramid." The challenge is to use the four identical pieces to form a symmetrical three-sided pyramid. I chose this prototype form, first, because I think the puzzle is elegant; second, because all four pieces are identical so only one template design is required; and third, because the pieces are fairly simple, geometrically, and thus so are the templates.

Step 1 — Assemble paper patterns



- Print the .pdf pattern attached to this project, or your own pattern, on the heaviest card stock you can get through your printer.
- I used some 100 lb cover stock I bought originally to bind screenplays, and would like something even heavier for next time. 
- Cut along all solid lines with scissors or an art knife, and mountain fold along all dashed lines.
- Assemble with Scotch tape, taking care to make the interior cavity as "watertight" as possible.
- Remember, unlike traditional papercraft models, tabs go on the outside of the joints, because it's the interior finish of the joint that is important. 

Step 2 — Melt metal



- Regardless of the equipment you have available, there is a casting metal suitable for your use.
- If all you've got is an old tin can and a kitchen stove, you can buy low-melting-point bismuth alloys that will melt in a pot of boiling water (100°C).
- If you have a gas hot plate and a nice ventilated (hopefully outdoor) space to work, you can melt old tire balancing weights, which are predominantly lead (melts at 330°C) and can be gathered from roads and parking lots everywhere. This is what I did.
- If you have a Gingery-style home foundry, you can achieve temperatures that make it easy to pour zinc alloys (420°C) or even aluminum (660°C).
- Note that there are realistic toxicity concerns with poor metal alloys containing lead and/or cadmium, and you should be careful to familiarize yourself with the risks associated with exposure to these metals before deciding to handle them yourself.



Step 3 — Bury pattern in sand



- The pattern needs to be buried with only the sprue protruding from the sand. Hardware store play sand would be my first recommendation, but two of the pieces pictured here were actually cast in table salt.
- Do not get any sand or salt inside the pattern itself. 
- Make sure the sand is uniformly packed around the pattern on all sides, without large voids that might collapse on exposure to the heat and weight of molten metal. 
- Vibrating the sand here, perhaps by setting it on a running washing machine, dryer, or car engine, is a better approach than tamping. 
- Mist the surface of the sand with water from a spray bottle to help hold everything together.

Step 4 — Pour metal



- Obviously one must be very careful when working with hot metal, even if it is a lower-melting alloy. Long sleeves, long pants, safety goggles, gloves, and closed-toed shoes are non-negotiable. 
- I melted my tire weights in a steel soup can, as shown above, and lifted it on and off the fire using a large pair of channel-lock pliers. 
- Even without any sort of formed-in spout it's not too hard to get the molten metal down the sprue, although as you can see I did splash a bit. 
- Make sure you pour well up into the sprue, because the metal will shrink as it cools and you want that shrinkage to come out of the waste sprue volume instead of the part itself. 

Step 5 — Open the mold



- Let your castings cool for at least an hour.
- Fish them out of the sand with a pair of pliers and dunk them in a can of room-temperature water.
- Leave them in the water for at least 10 minutes.
- Once the castings are cool enough to handle, pick them out of the water bath and remove the burnt paper wrapper with your fingers.

Step 6 — Clean up casting



- Cut the sprue off flush at its base using a hacksaw.
- Clean up any flash pointy bits with a sharp knife or wood chisel, and possibly a file.
- If you're working with lead- or cadmium-containing alloys, make sure to be cautious about the dust produced by any sawing or abrading operation.



Zinc and zinc alloys ("white metal") are the next step up from bismuth and/or lead-based metals, and can also usually be melted on a gas hotplate in a steel or iron pot. Zinc is of relatively low

toxicity, so long as you don't get it so hot that you cause it to burn, in which case inhalation of the zinc oxide smoke can cause "metal fume fever," which is not the end of the world but should definitely be avoided. It may have long-term health effects and, in any case, can make you feel lousy for a weekend. Zinc melts at 420°C and burns at 480°C, so it can be easy to burn it accidentally. You'll know if it happens: Zinc burns with an evil blue green flame, and makes great clouds of smoke. If this should happen to you, don't panic. Being careful not to breathe the smoke, turn off the heat and step back. And as the melt cools take a moment to observe and appreciate the thermochromicity of the zinc oxide layer on top: It's bright yellow at high temperatures but will turn back to chalk white as it cools.

The next big step up is aluminum. If you have the wherewithal to melt and pour aluminum in your shop, you probably don't need me to tell you how to do it. If you're curious, book one of Dave Gingery's classic 7-book DIY-machine-shop series is solely dedicated to the construction and operation of an ultra-low-cost home aluminum foundry. I have only attempted this paper pattern process with lead, but I don't see why it couldn't also work with hotter melts like zinc or aluminum. If you try it do let me know how it goes.

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